Rapid Healing of Scar-Associated Chronic Wounds After Ablative Fractional Resurfacing

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Background: Skin compromised by traumatic scars and contractures can manifest decreased resistance to shearing and other forces, while increased tension and skin fragility contribute to chronic erosions and ulcerations. Chronic wounds possess inflammatory mediators profiles and other characteristics, such as the presence of biofilms, that can inhibit healing.

Observations: Three patients with multiple traumatic scars related to blast injuries initiated a course of ablative fractional laser therapy for potential mitigation of contractures, poor pliability, and textural irregularity. Patients also had chronic focal erosions or ulcerations despite professional wound care. All patients experienced incidental rapid healing of their chronic wounds within 2 weeks of their initial ablative fractional laser treatment.

Conclusions: The unique pattern of injury associated with ablative fractional laser treatment may have various potential wound-healing advantages. These advantages include the novel concept of photomicrodebridement, including biofilm disruption and the stimulation of de novo growth factor secretion and collagen remodeling. If confirmed, ablative fractional resurfacing could be a potent new addition to traditional wound and scar treatment paradigms.


SKIN COMPROMISED BY TRAUMATIC SCARRING AND SPLIT-THICKNESS SKIN GRAFT PLACEMENT IS OFTEN FRAGILE AND CAN MANIFEST DECREASED RESISTANCE TO FRICTION AND OTHER FORCES COMPARED WITH UNAFFECTED SKIN. SCAR CONTRACTURES INCREASE SKIN TENSION AND DECREASE MOBILITY, POSSIBLY CONTRIBUTING TO CHRONIC EROSIONS AND ULCERATIONS. THESE ISSUES MAY IMPEDE REHABILITATION AFTER TRAUMATIC INJURIES BY LIMITING PROSTHETIC USE, INCREASING PAIN, AND INCREASING THE RISK OF INFECTION. ONE POSSIBLE BARRIER TO HEALING IN CHRONIC WOUNDS IS AN EXUBERANT AND PROLONGED INFLAMMATORY RESPONSE, A PROCESS THAT HAS BEEN LINKED TO BACTERIAL BIOFILMS. CHRONIC WOUNDS ALSO POSSESS INFLAMMATORY MEDIATOR PROFILES THAT ARE INHIBITORY AND CHARACTERIZED BY HIGH LEVELS OF PROTEASES. THESE PROTEASES CAN BREAK DOWN EXTRACELLULAR MATRIX GROWTH FACTORS AND IMPEDER WOUND HEALING BY LIMITING THE PROLIFERATION OF FIBROBLASTS, ENDOTHELIAL CELLS, AND KERATINOCYTES.

The association of ablative fractional resurfacing (AFR) with cosmetic enhancements in aged and photodamaged skin is increasingly well documented in the literature. Furthermore, several reports have described cosmetic and even functional improvements in traumatic scars and contractures after AFR. However, to our knowledge, the potential application of this technique to facilitate the healing of scar-associated chronic wounds has not been addressed specifically. We herein present a series of patients who experienced rapid and sustained healing of longstanding erosions and ulcers associated with traumatic scars and split-thickness skin grafts after initiating a course of AFR. We propose that AFR may exert its effects in part through a microfractional laser debridement phenomenon.

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REPORT OF A CASE

A 26-year-old serviceman presented to the dermatology clinic approximately 5 months after stepping on an improvised...
explosive device in Afghanistan while on dismounted patrol, resulting in extensive injuries and bilateral above-knee and right above-elbow amputations. He had been engaged in a comprehensive daily or alternate-day rehabilitative program during the preceding months that included skilled physical and occupational therapy and dedicated wound care. Therapy included scar massage, strengthening and range-of-motion exercises, neuromuscular reeducation, prosthetic training, functional activity training, and gait training.

At presentation, his primary concerns were skin fragility, sensitivity, and multiple nonhealing areas at a split-thickness skin graft site on his right amputation stump. These issues had precluded progression in the prosthetic rehabilitation of his lower extremity. At presentation, his wound care regimen consisted of daily application of petrolatum or topical bacitracin ointment and intermittent application of silver-impregnated foam dressings (Mepilex Ag; Mölnlycke Health Care). In addition, the patient noted sensitivity of the adjacent skin exacerbated by hair pulling by his prosthetic liner. Examination revealed a maturing split-thickness skin graft with textural and pigmentary irregularity overlying moderate heterotopic ossification. Multiple focal erosions and shallow ulcerations were noted in addition to poor skin pliability and moderate invaginations intermittently at junctions of the graft and adjacent skin (Figure, A).

A course of AFR was proposed in an attempt to improve the patient’s scar contractures, skin pliability, and textural irregularity. As such, the patient received treatment with a 10.6-µm ablative fractional carbon dioxide laser system (Deep FX laser and UltraPulse Encore system; Lumenis, Ltd) to the entire graft site and a 1- to 2-mm rim of normal skin. The selected pulse energy of 50 mJ was proportional to the perceived scar thickness and desired treatment depth. The spot size (microcolumn width) and pulse width were fixed at approximately 120 µm and 250 microseconds, respectively. All treatments were delivered with a single pulse and single pass, without overlap, at a treatment density of 5%. Postprocedure care included application of petrolatum for 2 to 3 days after treatment. Physical and occupational therapy as already detailed were allowed to resume immediately after treatment.

In addition to AFR, the patient received focal laser hair reduction over the distal aspect of his stump in hair-bearing areas with associated sensitivity. Significant interval wound healing at the graft site was noted at his first post-treatment visit. Cumulative and sustained improvements were observed 8 months after his initial treatment and 6 months after a second fractional laser treatment.
follow-up approximately 1 week after his initial treatment (Figure, B). Continued improvement was noted at follow-up approximately 2 months after his initial treatment, with nearly total remission of all previous erosions and ulcers despite significant advancement in his prosthetic use. Interval enhancements in texture, pigmentation, and skin pliability were also appreciated (Figure, C). Persistent and cumulative improvements were noted 8 months after his initial treatment and 6 months after a second AFR treatment, despite extended prosthetic use (Figure, D).

Two additional patients with comparable mechanisms of injury were treated in a similar fashion, yielding equally favorable functional and aesthetic responses (Table).

Table. Summary of Patient Demographic and Treatment Data

<table>
<thead>
<tr>
<th>Age, y</th>
<th>Injury Mechanism and Location</th>
<th>Interval From Injury to Presentation, mo</th>
<th>Treatment Location</th>
<th>Physical Findings at Presentation</th>
<th>Laser Pulse Energy, mJ^\text{a}</th>
<th>Treatment Interval, wk/Total No. of Treatments</th>
<th>Follow-up, mo</th>
<th>Postprocedure Improvements</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
<td>Improvised explosive device; Bil above-knee and R above-elbow amputation</td>
<td>5</td>
<td>R amputation stump, distal aspect</td>
<td>Restrictive split-thickness skin graft site associated with multiple nonhealing erosions and ulcerations; skin fragility and poor pliability</td>
<td>50</td>
<td>8/2</td>
<td>8</td>
<td>Improvements in texture, pigmentation, and skin pliability; almost complete resolution of erosions by 2 mo; increased tolerance for extended prosthetic use during follow-up</td>
</tr>
<tr>
<td>28</td>
<td>Improvised explosive device; Bil above-knee amputation</td>
<td>6</td>
<td>R amputation stump, distal aspect</td>
<td>Contracted, erythematous, focally hypertrophic graft site with persistent, angulated erosion</td>
<td>30</td>
<td>8/2</td>
<td>6</td>
<td>Complete reepithelialization of erosion by PO day 6; overall improved skin texture and pliability of the graft site; extended prosthetic use without recurrence of erosion during follow-up</td>
</tr>
<tr>
<td>39</td>
<td>Detonation injury; distal R arm and hand amputation and 30% TBSA burns</td>
<td>60</td>
<td>R elbow, lateral aspect and distal forearm skin</td>
<td>Persistent 0.8 × 1.5-cm ulcer and scar contracture with decreased extension of R forearm and fragile, restrictive, and poorly pliable skin</td>
<td>50 and 30</td>
<td>6/3</td>
<td>14</td>
<td>Sustained healing of the ulcer during follow-up; cumulative improvements in skin pliability and forearm range of motion with each treatment</td>
</tr>
</tbody>
</table>

Abbreviations: Bil, bilateral; PO, postoperative; R, right; TBSA, total body surface area.
^\text{a} All treatments were performed with a single pass and single pulse, without overlap, at a density of 5%. Selected pulse energy was proportional to estimated scar thickness.

Chronic wounds are characterized by phenotypic changes, including evidence of cell senescence with a lack of secretion and response to growth factors.\textsuperscript{3}-\textsuperscript{5} Debridement has been long established as a means to remove poorly healing areas from wounds and to promote replacement with healthier tissue. However, this process can be invasive and may require significant downtime, particularly in areas where amputation stumps contact prostheses.

Fractionated lasers create microscopic wounds that can reach greater dermal depths than previously attainable with full-field devices, while relatively large adjacent areas of untreated skin may facilitate rapid healing. Several histopathologic studies\textsuperscript{16-26} involving AFR in normal skin demonstrate the sequential generation of a multitude of growth factors and cytokines at the treatment site with varying dynamics over time. The coordinated expression of heat shock proteins, matrix metalloproteinases, growth factors, and other mediators leads to early epidermal regrowth and the induction of a collagen-remodeling response that has been shown to persist 6 months or more after treatment. Histologically, reepithelialization occurs within 24 to 48 hours, with epidermal invagination into the ablated zones during the first week. This process is followed by replacement of the ablation zone with newly synthesized collagen and long-term remodeling.\textsuperscript{18-21}

Although little is known about the details of the histopathologic response of scar tissue to AFR, the process probably follows similar molecular pathways. This unique pattern of discrete ablative microcolumns may provide various wound-healing advantages, affording a means to reverse the long-standing changes seen in these chronic wounds with a minimally invasive treatment. One putative mechanism that may have applications across all types of chronic wounds is the disruption of bacterial biofilms. We propose the term photomicrodebridement for the process of applying AFR to vaporize a portion of dysfunctional scar tissue and wound debris.

Alterations in adjacent skin from burns or other trauma, such as increased tension and fragility, likely contribute to a microenvironment that promotes chronic wounds. Although normal dermis has a relatively fine
3-dimensional basket-weave pattern, scar tissue is characterized by the presence of thick parallel bundles of cellular collagen. The controlled removal of a portion of dysfunctional scar and the stimulation of deep dermal cells to promote diffuse collagen remodeling may provide a second possible mechanism facilitating the healing of chronic wounds associated with scars and contractures. The principle of deliberately producing a pixilated skin injury to stimulate a wound-healing response with associated neocollagenesis and collagen remodeling has long been practiced in the form of skin needling. The enhancements in scar texture, pliability, durability, mobility, and dyschromia observed in the cases described herein are consistent with our overall experience during the course of thousands of AFR treatments. Although future confirmatory histopathologic studies are required, we hypothesize that a relative normalization of the epidermal and dermal architecture is responsible for the improvements in appearance and functionality of the treated skin.

In summary, we present herein a series of cases in which AFR was associated with incidental rapid and sustained healing of scar-related chronic erosions and ulcers, with clear benefits to the patients in terms of enhanced rehabilitation. Based on our experience, indications in this series suggest that AFR demonstrates efficacy for scars in patients with a range of ages and wound locations. Two of the patients in this series were treated less than 1 year after injury, in contrast to existing scar treatment paradigms for procedural intervention. In our experience, treatment variables should be individualized at each therapy session largely on the basis of estimated scar thickness and degree of restriction. Higher pulse energies selected for thicker, restrictive scars require a concomitant decrease in treatment density to avoid bulk heating and potentially worse scarring. In our practice, traumatic scars are treated usually at the lowest available density setting. Atrophic scars or areas with minimal textural or pigmented irregularity may be treated with lower pulse energies and a somewhat higher density. Less mature scars within 1 year of injury seem to be more susceptible to breakdown with aggressive modality treatment. Therefore, judicious settings and single-modality treatment sessions are recommended within the first year of injury. Future prospective studies will be required to determine optimal treatment variables inclusive of other factors, such as the age and location of the scar and adjunctive treatments.

We must consider limitations when drawing conclusions from this series. Although histological analysis of pretreatment and posttreatment scar tissue would strengthen the association of AFR with the observed clinical enhancements, the risks of additional poorly healing wounds or infections in this setting precluded the use of such tests. Furthermore, the inherent heterogeneity of traumatic injuries makes the accumulation of a large homogeneous series particularly challenging and will have to be accounted for during future inquiry. Prospective studies are certainly required to clarify any potential role for AFR as an adjunct to traditional wound management and in applications for the management of traumatic scars in general. If confirmed, traditional wound and scar treatment paradigms could shift toward earlier intervention with anticipated benefits in rehabilitation and a more favorable trajectory for wound healing.

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Conflicts of Interest Disclosures: Dr Waibel has been employed by Palm Beach Aesthetics Dermatology, Miami Dermatology and Laser Institute, and Dermatology Institute of Southwest Ohio; has consulted for Medicis and Lumenis; has received honoraria from Sciton, Lumenis, Syneron/Candela, Medicis, Allergan, and Solta; has served on the speakers bureau of Sciton, Lumenis, Syneron/Candela, Medicis, Allergan, and Solta; has provided expert testimony for renewed cases; has received grants from Sciton, ASDS, and Lumenis; receives royalties for patent UMK-193 at the University of Miami; and has received donated equipment from Palomar, Alma, Cel- leration, Syneron/Candela, Sciton, Deka, and Solta.

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REFERENCES


